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Naval Postgraduate School
Monterey, California 93943-5138

SUMMARY OF RESEARCH 1998

Department of Physics

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Chair

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Prepared for: Naval Postgraduate School
Monterey, CA 93943-5000

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13. ABSTRACT (Maximum 200 words.)

This report contains summaries of research projects in the Department of Physics. A list of recent publications is also included which consists of conference presentations and publications, books, contributions to books, published journal papers, technical reports, and thesis abstracts.

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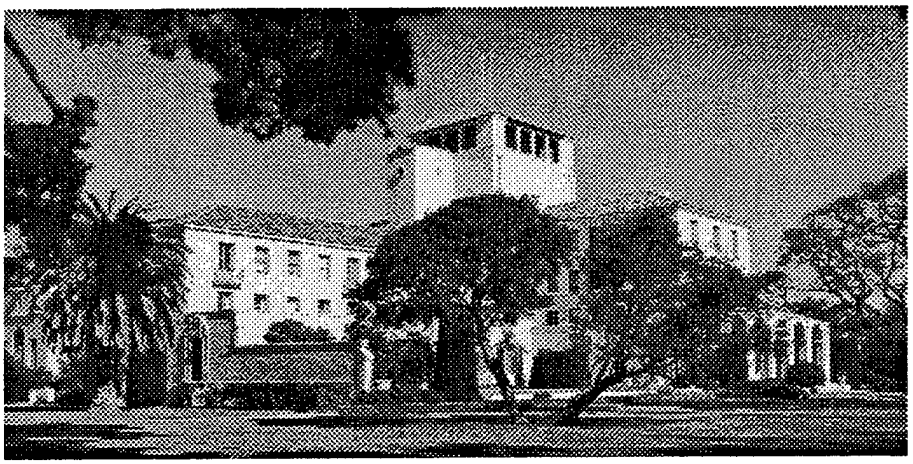
DEPARTMENT OF PHYSICS

William B. Maier
Chair

THE NAVAL POSTGRADUATE SCHOOL MISSION

The mission of the Naval Postgraduate School is to increase the combat effectiveness of U.S. and Allied armed forces and enhance the security of the USA through advanced education and research programs focused on the technical, analytical, and managerial tools needed to confront defense-related challenges.



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PREFACE

Research at the Naval Postgraduate School is carried out by faculty in the School's eleven academic departments, seven interdisciplinary groups, and the School of Aviation Safety. This volume contains research summaries for the projects undertaken by faculty in the Department of Physics during 1998. Also included is an overview of the department, faculty listing, a compilation of publications/presentations, and abstracts from theses directed by the department faculty.

Questions about particular projects may be directed to the faculty Principal Investigator listed, the Department Chair, or the Department Associate Chair for Research. Questions may also be directed to the Office of the Associate Provost and Dean of Research. General questions about the NPS Research Program should be directed to the Office of the Associate Provost and Dean of Research at (831) 656-2099 (voice) or research@nps.navy.mil (e-mail). Additional information is also available at the RESEARCH AT NPS website, http://web.nps.navy.mil~code09/.

INTRODUCTION

The research program at the Naval Postgraduate School exits to support the graduate education of our students. It does so by providing militarily relevant thesis topics that address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain the long-term superiority of the Navy/DoD. It keeps our faculty current on Navy/DoD issues, permitting them to maintain the content of the upper division courses at the cutting edge of their disciplines. At the same time, the students and faculty together provide a very unique capability within the DoD for addressing warfighting problems. This capability is especially important at the present time when technology in general, and information operations in particular, are changing rapidly. Our officers must be able to think innovatively and have the knowledge and skills that will let them apply technologies that are being rapidly developed in both the commercial and military sectors. Their unique knowledge of the operational Navy, when combined with a challenging thesis project that requires them to apply their focussed graduate education, is one of the most effective methods for both solving Fleet problems and instilling the life-long capability for applying basic principles to the creative solution of complex problems.

The research program at NPS consists of both reimbursable (sponsored) and institutionally funded research. The research varies from very fundamental to very applied, from unclassified to all levels of classification.

- Reimbursable (Sponsored) Program: This program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policymakers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. The sponsored program utilizes Cooperative Research and Development Agreements (CRADAs) with private industry, participates in consortia with other government laboratories and universities, provides off-campus courses either on-site at the recipient command or by VTC, and provides short courses for technology updates.

- NPS Institutionally Funded Research Program (NIFR): The institutionally funded research program has several purposes: (1) to provide the initial support required for new faculty to establish a Navy/DoD relevant research area, (2) to provide support for major new initiatives that address near-term Fleet and OPNAV needs, (3) to enhance productive research that is reimbursable sponsored, (4) to contribute to the recapitalization of major scientific equipment, and (5) to cost-share the support of a strong post-doctoral program.

- Institute for Joint Warfare Analysis (IJWA) Program: The IJWA Program provides funding to stimulate innovative research ideas with a strong emphasis on joint, interdisciplinary areas. This funding ensures that joint relevance is a consideration of research faculty.

In 1998, the overall level of research effort at NPS was 145 faculty workyears and exceeded $35 million. The Department of Physics' effort was 8.07 faculty workyears and exceeded $1.5 million. The sponsored research program has grown steadily to provide the faculty and staff support that is required to sustain a strong and viable graduate school in times of reduced budgets. In FY98, over 81% percent of the NPS research program was externally supported. In the Department of Physics 75% was externally supported.

The department's research sponsorship in FY98 is provided in Figure 1.

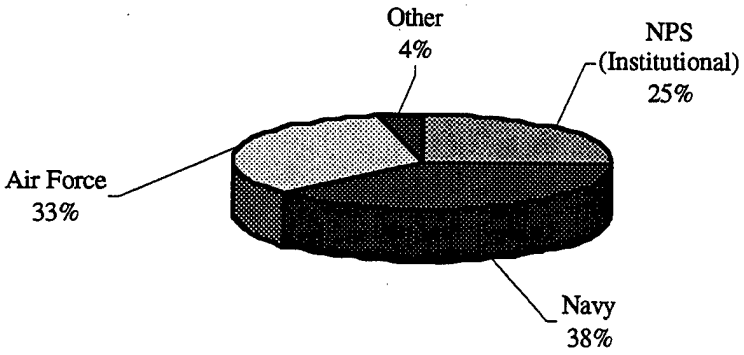

Figure 1. FY98 Sponsor Profile of the Department of Physics

These are both challenging and exciting times at NPS and the research program exists to help ensure that we remain unique in our ability to provide graduate education for the warfighter.

DAVID W. NETZER
Associate Provost and Dean of Research

October 1999

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DEPARTMENT SUMMARY

The following pages summarize the progress made in CY98 on 21 research projects conducted by ten Physics Department faculty members, broadly categorized into the following topic areas. The number of projects in each topic area is given in parenthesis. Also listed for each project category are the professor's name(s).

Atmospheric Physics (Aerosol Formation, Turbulence) (3):
- Research Associate Professor Donald Speil
- Professor Donald L. Walters

Chemical/Biological Warfare (1):
- Associate Professor Robert C. Harney

Directed Energy Weapons (Free Electron Laser) (2):
- Professor William B. Colson

Physical Acoustics (4):
- Associate Professor Bruce Denardo
- Associate Professor Andres Larraza

Physics Education (1):
- Associate Professor Bruce Denardo

Plasma Physics (1) :
- Associate Professor Richard C. Olsen

Remote Sensing (3):
- Associate Professor Richard C. Olsen

Solid State Physics (1):
- Associate Professor James Luscombe

Underwater Acoustics (Experiment, Propagation, Sonar Arrays) (5):
- Associate Professor Steven R. Baker
- Assistant Professor Kevin B. Smith

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MEASUREMENTS OF THE UNDERWATER ACOUSTIC AMBIENT NOISE IN THREE LARGE TANK EXHIBITS AT THE MONTEREY BAY AQUARIUM

Steven R. Baker, Associate Professor
Department of Physics
Sponsor: Unfunded

OBJECTIVE: To measure the underwater acoustic ambient noise in the three large tank exhibits at the Monterey Bay Aquarium, and to compare these measurements to underwater ambient noise measurements made in the Monterey Bay.

SUMMARY: Measurements were made of the underwater acoustic ambient noise in three large tank exhibits at the Monterey Bay Aquarium: the Kelp Forest Exhibit (335,000 gal), the Monterey Bay Habitats Exhibit (350,000 gal), and the Outer Bay Waters Exhibit (1.4 million gal). A single, calibrated, Navy type DT-276 was used. The hydrophone output voltage was preamplified and recorded using a 16-bit digital audio tape recorder, with a sampling rate of 48 kHz. Measurements were made with various mechanical equipment (motors, fans, pumps, sprinklers, wave machine) turned on and off. On one occasion, the noise was measured in the largest tank, the Outer Bay Waters Exhibit, during a complete power shutdown. For comparison, measurements were also made at several locations and depths in the inner Monterey Bay. One-third octave band and narrow-band analyses were performed. Comparisons were made between the aquarium and bay results, and standard deep-water acoustic ambient noise spectral density curves.

PUBLICATIONS:

O'Neal, Daniel M. and Baker, Steven R., "Results of Underwater Ambient Noise Measurements in Three Large Tank Exhibits at the Monterey Bay Aquarium," *Proceedings of the 16th International Congress on Acoustics and the 135th Meeting of the Acoustical Society of America*, Vol. II, pp. 1411-1412, 1998.

O'Neal, Daniel M. and Baker, Steven R., "Results of Underwater Ambient Noise Measurements in Three Large Tank Exhibits at the Monterey Bay Aquarium," abstract in *Journal of the Acoustical Society of America*, Vol. 103, p. 2908, 1998.

CONFERENCE PRESENTATIONS:

O'Neal, Daniel M. and Baker, Steven R., "Results of Underwater Ambient Noise Measurements in Three Large Tank Exhibits at the Monterey Bay Aquarium," Joint Meeting of the International Congress of Acoustics and the Acoustical Society of America, Seattle, WA 20-26 June 1998.

THESIS DIRECTED:

O'Neal, Daniel Matthew, "Comparison of the Underwater Ambient Noise Measured in Three Large Exhibits at the Monterey Bay Aquarium and in the Inner Monterey Bay," Master's Thesis, Naval Postgraduate School, June 1998.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Bioacoustics, Underwater Ambient Noise, Aquarium

NUMERICAL MODELING OF SONAR TRANSDUCERS AND ARRAYS

Steven R. Baker, Associate Professor
Department of Physics
Clyde L. Scandrett, Associate Professor
Department of Mathematics
Sponsor: Office of Naval Research

OBJECTIVE: To continue development of the T-matrix method for the numerical modeling of arbitrarily densely- and randomly-packed sonar arrays. Specifically, the objectives for FY98 were to: (1) obtain the upgraded version of the ATILA finite-element code (for the analysis of sonar transducers) and arrange for it to include the ability to compute the scattering of acoustic waves for arbitrary incidence; (2) refine the mesh of our ATILA model for a fluid-loaded elastic spherical shell and compare the T-matrix elements computed using this model with the results previously obtained using the coarser model and with exact analytical values; (3) collaborate with colleagues at NUWC to compute the T-matrix elements for a transducer of interest using an ATILA model; and (4) continue to investigate the feasibility of coupling an ATILA model for the transducer structure to a specialized code for computing acoustic scattering, with particular attention to the nearfield.

SUMMARY: Objectives 1, 2, and 4 were accomplished. The new version of the ATILA code was upgraded to include the ability to compute acoustic scattering for arbitrary incidence and was ported to Professor Baker's SGI workstation. It was not possible to refine the existing meshes in a sensible way, with the refinement tools built into ATILA, so a new mesh was created. This mesh will be tested and refined in FY99. Three candidate schemes were applied for computing the single-scattering T-matrix to a test problem, that of a thin spherical steel shell in water, and the results were evaluated against analytical results obtained using thin-shell theory. The three were: (1) an ATILA-only method, employing its built-in radiation dampling elements; (2) a method employing only SYSNOISE, a commercial finite-element code for computing acoustic fields; and (3) a method which features ATILA coupled to another code from ISEN, called EQI, for computing acoustic fields. The three methods differ mainly in the way in which the radiation boundary is modeled. From the results, it was concluded that the combination of ATILA coupled with EQI is the most promising for future development of the T-matrix method applied to active sonar arrays. Detailed results are given in the reports listed below.

PUBLICATION:

Scandrett, C.L. and Baker, S.R., "T-Matrix Approach to Array Modeling, Naval Postgraduate School Technical Report, NPS-UW-98-001, October 1998.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Active Sonar, Transducer, Array, Numerical Modeling, Finite-Elements

SHIP DEFENSE WITH FREE ELECTRON LASERS

William B. Colson, Professor
Department of Physics
Sponsor: Naval Postgraduate School

OBJECTIVE: The free electron laser has a unique pulse format where a sequence of picosecond long pulses may damage materials more efficiently than the more typical cw laser. Research is proposed to study free electron laser damage.

SUMMARY: The free electron laser at Thomas Jefferson National Accelerator Facility has reached a power level of several hundred watts. The power density required for defense against sea-skimming missiles is 10 kW per square centimeter. When the laser is focussed to a spot-size of about one square millimeter, the intensity matches that required for missile defense and represents a fairly large macroscopic area.

PUBLICATION:

Colson, W.B., "Short-Wavelength Free Electron Lasers in 1997," *Nuclear Instruments and Methods in Physics Research,* A407, pp. 26-29, 1998.

CONFERENCE PRESENTATIONS:

Colson, W.B., "Short-Wavelength Free Electron Lasers in 1997," poster presentation, Twentieth International Free Electron Laser Conference, Williamsburg, VA, August 1998.

THESIS DIRECTED:

Herbert, Paul A., "Anti-Ship Missile Defense and the Free Electron Laser," Master's Thesis, December 1998.

PATENTS:

Robinson, Kem E., Gottschalk, Stephen C., Quimby, David C., and Colson, William B., Patent Application Number 08/55,731: "Optical Mode Tapered Undulator and Method for Producing the Same."

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Directed Energy Weapons

KEYWORDS: Free Electron Laser, Industrial Laser Processing

HIGH POWER INFRARED FREE ELECTRON LASERS FOR SHIP DEFENSE

William B. Colson, Professor
Department of Physics
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: To research studies of the high average power infrared wavelength free electron lasers at the Thomas Jefferson National Accelerator Facility, Newport News, VA. SPAWAR is developing the technology for using free electron lasers (FELs) to defend ships against sea-skimming missiles.

SUMMARY: NPS is working with Jefferson National Accelerator Facility and SPAWAR to develop the superconducting accelerator technology for a high power laser. The design must meet the requirements for a high-power shipboard laser weapon. During the year, the laser began operation for the first time and developed a power of 500 Watts.

PUBLICATIONS:

Kesselring, M., Colson, W.B., Wong, R., and Sheffield, R.L., "Simulations of the LANL Regenerative Amplifier FEL," *Nuclear Instruments and Methods in Physics Research,* A407, II-23, 1998.

Nguyen, R.T., Colson, W.B., Wong, R., and Sheffield, R.L., "Simulations of a Regenerative MW FEL Amplifier," *Nuclear Instruments and Methods in Physics Research,* A407, II-3, 1998.

CONFERENCE PRESENTATION:

LeGear, R.E., Steele, R.B., McGinnis, R.D., and Colson, W.B., "Simulations of the Proposed TJNAF 20 kW Free Electron Lasers," poster presentation at the Twentieth International Free Electron Laser Conference, Williamsburg, VA, August 1998.

THESES DIRECTED:

LeGear, R. Eric, "Simulations of Proposed 20 kW Klystron Free Electron Laser," Master's Thesis, June 1998.

Steele, Richard B., "Simulations of Proposed TJNAF 20 kW Free Electron Laser," Master's Thesis, June 1998.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Directed Energy Weapons

KEYWORDS: Free Electron Laser, High Energy Laser

PARAMETRIC EXCITATION

Bruce Denardo, Associate Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVES: To excite a sound mode in a gas-filled resonator by parametric excitation (modulating a parameter upon which the resonance frequency depends). When this occurs in any oscillator, the response amplitude grows exponentially until it is saturated by a nonlinearity of the system. Hence, large response amplitudes may be possible. Another goal was to determine the mechanism that saturates the growth. If large amplitudes can be obtained, this research may lead to the use of parametric drives in various practical devices such as thermoacoustic refrigerators, acoustic compressors, acoustic pumps, and intense underwater sound sources. In a related project, the goal was to perform experimental, analytical, and numerical investigations of the newly-discovered parametric instability of a general system of two weakly coupled nonlinear oscillators.

SUMMARY: Parametric excitation was attempted for a double Helmholtz resonator (two cavities connected by a neck) for two different types of drive. In the first case, the neck was constructed to be similar to a trombone slide, so that the neck length could be modulated by a shaker. The maximum drive amplitude was not expected to exceed the threshold condition for excitation, but the experiment was pursued to observe whether the effective quality factor of the mode increased with increasing parametric drive amplitude, according to the theory. Surprisingly, the quality factor *decreased*, which was found to be the caused by turbulence. In the second system, the cavity volumes were modulated by pistons. This drive was predicted to exceed threshold, but parametric excitation did not occur. The reason for this is currently being sought. In the coupled-oscillator project, a finite-amplitude instability of one of the normal modes of a system of two weakly coupled nonlinear oscillators was determined to be caused by the mode parametrically driving the other normal mode, which is stable. The investigations yielded an understanding of the behavior, some of which was surprising. For example, natural qualitative reasoning leads to the conclusion that the stable mode should be unstable and the unstable mode should be stable.

PUBLICATIONS:

Prather, Wayne E., Denardo, Bruce, and Raspet, Richard, "Parametric Excitation of a Helmholtz Resonator," *Journal of the Acoustical Society of America,* Vol. 103, No. 5, Pt. 2, p. 2765, 1998.

Denardo, Bruce, Earwood, John, and Sazonova, Vera, "Parametric Instability of Two Coupled Nonlinear Oscillators," *American Journal of Physics*, 1999, to be published.

CONFERENCE PRESENTATION:

Prather, Wayne E., Denardo, Bruce, and Raspet, Richard, "Parametric Excitation of a Helmholtz Resonator," Acoustical Society of America, Seattle, WA, 20-26 June 1998.

DoD KEY TECHNOLOGY AREAS: Other (Acoustical Resonators, Nonlinear Oscillations)

KEYWORDS: Parametric Excitation, Instability, Nonlinear Oscillations

SOLITONS

Bruce Denardo, Associate Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: To theoretically and experimentally investigate the possibility of generating solitons (self-localized nonlinear waves that act as particles) in a bar of sandstone. An observation of a soliton in rock would be the first of its kind. In another project, the goal was to experimentally investigate mode hopping for an annular channel of water with parametrically driven surface waves. The transition of one standing wave mode to another in this system involves a localized kink soliton.

SUMMARY: New types of solitons solutions were discovered for a class of systems with nonanalytic nonlinearities. (A *nonanalytic* function has a discontinuity in the function or any derivative of it.) The unusual behavior of the frequency of compressional standing waves in sandstone as a function of amplitude allows this medium to be modeled with a nonanalytic nonlinearity. Similar behavior occurs for clocks with flexible pendulums interrupted by sandwiched circular disks, which were experimentally investigated by Huygens in the 1600s. Nonanalytic soliton solutions for sandstone were obtained, and the experimental generation of these solitons was determined to be feasible. Experiments were performed, but the solitons could not be generated due to various complications, including the mode structure being complicated by shear waves. In the mode hopping project, the behavior of the up-hopping and down-hopping instabilities was mapped in the plane of drive amplitude vs. drive frequency. The low-amplitude data was fit by Mathieu curves.

PUBLICATION:

Denardo, Bruce, "Nonanalytic Nonlinear Oscillations: Christiaan Huygens, Quadratic Schrödinger Equations, and Solitary Waves," *Journal of the Acoustical Society of America,* Vol. 104, pp. 1289-1300, 1998.

DoD KEY TECHNOLOGY AREAS: Other (Solitons)

KEYWORDS: Solitons, Nonanalytic Nonlinearity, Mode Hopping

ELECTRICAL RESISTIVE NETWORKS

Bruce Denardo, Associate Professor
Department of Physics
Sponsor: University of Mississippi

OBJECTIVES: To perform experiments and numerical simulations of several types of large electrical resistive networks and to compare the results to the existing theories. Electrical networks are useful as an augmentation of an Ohm's law experiment in the educational laboratory and as lecture demonstrations. In addition, the work has applications to modeling for geophysical exploration with electrical currents and to petroleum flow in oil wells.

SUMMARY: Two resistive networks were considered. In the first, the equivalent resistance was measured across the ends of a ladder whose number of loops was incremented until the precision of the ohmmeter was exceeded. In the second, resistances were measured across nodes near the center of a 12 by 12 square grid of resistors. In the ladder experiment, the approximate exponential decrease in current in successive loops had several important consequences. In the square grid experiment, the algebraic decrease in current with distance from the ohmmeter terminals similarly had important consequences. The square grid results gave approximate confirmation of complicated theoretical calculations for the equivalent

resistance across two nonadjacent nodes of an infinite square lattice. The experimental results were verified numerically by a relaxation method and alternatively with commercial software.

PUBLICATIONS:

Denardo, Bruce, Earwood, John, and Sazonova, Vera, "Experiments With Electrical Resistive Networks," *American Journal of Physics*, 1999 to be submitted.

DoD KEY TECHNOLOGY AREAS: Other (Educational Physics, Geophysical Exploration and Oil Flow)

KEYWORDS: Electrical Networks, Equivalent Electrical Resistance, Ohm's Law

DETECTION AND CLASSIFICATION OF CHEMICAL AND BIOLOGICAL AGENTS

Robert C. Harney, Associate Professor
Department of Physics
Sponsor: Naval Postgraduate School

OBJECTIVE: To determine the feasibility through analyses and component demonstrations of developing a sensor for the remote detection and classification of chemical and biological warfare agents using a frequency tunable ultraviolet laser in a spectroscopic Raman lidar system.

SUMMARY: A strawman system concept has been developed for a Raman lidar system adaptable to detecting and classifying chemical and biological warfare agents. A moderate-prf, pulsed ultraviolet laser would be scanned over the scene of interest. Returns from the scene would be optically filtered to remove reflected laser radiation, leaving only wavelength-shifted signals due to fluorescence and/or Raman scattering, which would be detected by fast photon counting electronics. Such signals are strongly indicative of contamination by biological (mostly fluorescence) or chemical (usually Raman scattering) aerosols or films. Upon detection of sufficient contamination to warrant classification, the lidar will be electronically reconfigured to transmit alternate longer- and shorter-wavelength ultraviolet pulses in a fixed direction. The returns for each transmitted wavelength will be spectroscopically analyzed, detected, and separately recorded. After sufficient observation time (seconds?) the two spectra will be subtracted (this process eliminates much of the fluorescence signal, leaving an enhanced Raman signal. The Raman signal will be analyzed using traditional spectral analysis algorithms and an a priori database of chemical and biological spectral signatures to classify the contaminant.

The laser is the long pole in the tent of this problem; acceptable laser sources are not currently available. It is essential to validate the availability of a laser source with the required wavelength tunability and pulse energy characteristics. Analysis indicates that the laser must be capable of rapidly switching from one wavelength to another and emit millijoules of energy at hundreds of Hz prf. We are currently constructing a tunable ultraviolet laser based on flashlamp pumping of the newly-available Ce:LiSAF laser crystal to determine if it can be used to solve this problem. Assembly of a breadboard laser has been completed. No laser output has yet been detected, although precision alignment of the device is on hold until the student return from his temporary assignment to the CNO Strategic Studies Group in Newport, RI. If lasing can be detected, the performance characteristics of the device will be measured. Although the breadboard will not demonstrate rapid wavelength switching nor demonstrate high prf, extension to these regimes is usually a design and fabrication exercise, if the requisite pulse energy can be obtained from a rod of reasonable size and tunability can be demonstrated.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Chemical Warfare, Biological Warfare, Detector, LIDAR

PROJECT SUMMARIES

INVESTIGATIONS OF LINEAR AND NONLINEAR ACOUSTIC NOISE

Andrés Larraza, Assistant Professor
Department of Physics
Sponsors: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: To perform experimental and numerical investigations of nonlinear acoustic noise in one dimension, and linear acoustic noise in a new area that we refer to as *Casimir acoustics*.

SUMMARY: Besides probing a variety of fundamental issues, our nonlinear noise research may have applications to noise generation and control, especially in regard to supersonic vehicles. An understanding may lead to techniques to actively suppress the development of shocks. The notion that acoustic noise can test, by analogy, predictions due to stochastic electrodynamics and to electromagnetic zero point field (ZPF) effects has been established recently by measurements of the force law between two rigid, parallel plates due to the radiation pressure of broadband acoustic. This measurement constitutes an acoustic analog to the Casimir effect which is the force of attraction between two closely spaced uncharged parallel conducting plates due to the ZPF. However, in contrast to the ZPF Casimir effect, band limited acoustic noise can cause the force to be attractive *or* repulsive as a function of separation between the plates. Our long-term interest in this research is to exploit linear and nonlinear acoustic noise as a system to probe fundamental physics. While nonlinear acoustic noise can probe the physics of wave systems that are driven far off equilibrium, linear acoustic noise can test, by analogy, predictions due to the ZPF which are difficult or impossible to directly verify by experiments.

PUBLICATIONS:

Larraza, A., Holmes, C.D., Susbilla, R.T., and Denardo, B., "The Force Between Two Parallel Rigid Plates Due to the Radiation Pressure of Broadband Noise: In Acoustic Casimir Effect," *Journal of the Acoustical Society of America*, Vol. 103, pp. 2267-2272, published as a Selected Research Article, 1998.

Larraza, A. and Denardo, B., "An "Acoustic Casimir Effect," *Physics Letters A*, Vol. 248, pp. 151-155, 1998.

Larraza, A., "A Demonstration Apparatus for an Acoustic Analog the Casimir Effect," *American Journal of Physics*, 1999, to appear.

Larraza, A., "Some Acoustic Analogs to Zero Point Field Effects," *Quantum Aspects of Beam Physics,* P. Chen, (ed.), World Scientific, 1998, to appear.

Simmons, T., Denardo, B., Larraza, A., and Keolian, R., "Acoustic Radiometer Demonstration," *Proceedings of the 16th International Conference on Acoustics,* Vol. 1, Patricia K. Kuhl and Lawrence A. Crum, (eds.), pp. 129-130, 1998.

Larraza, A., Holmes, C.D., Susbilla, R.T., and Denardo, B., "An Acoustic Casimir Effect," *Proceedings of the 16th International Conference on Acoustics*, Vol. 1, Patricia K. Kuhl and Lawrence A. Crum, (eds.), pp. 131-132, 1998.

Simmons, T., Denardo, B., Larraza, A., and Keolian, R., "An Acoustic Radiometer," *Journal of the Acoustical Society of America*, Vol. 103, No. 5, Pt 2, p. 2763, 1998.

Larraza, A., Holmes, C.D., Susbilla, R.T., and Denardo, B., "An Acoustic Casimir Effect," *Journal of the Acoustical Society of America*, Vol. 103, No. 5, Pt 2, p. 2763, 1998.

CONFERENCE PRESENTATION:

Larraza, A., "Some Acoustic Analogs to Electromagnetic Zero Point Field Effects: Static and Dynamic Casimir Effects," Advanced ICFA Beam Dynamics Workshop on Quantum Aspects of Beam Physics, Monterey, CA, 4-9 January 1998.

THESIS DIRECTED:

Chan, E.J., "Acoustic-Induced Drag on a Bubble," Master's Thesis, Naval Postgraduate School, December 1998.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Nonlinear Waves, Random Waves

LINEAR AND NONLINEAR ACOUSTIC NOISE

Andrés Larraza, Assistant Professor
Bruce Denardo, Associate Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: To perform experimental, analytical, and numerical investigations of nonlinear acoustic noise in one dimension and linear acoustic noise in a new research area referred to as *Casimir acoustics*. While one-dimensional nonlinear acoustic noise probes the physics of wave systems that are driven far off equilibrium, linear acoustic noise can test, by analogy, predictions due to the quantum electromagnetic zero-point field that are difficult or impossible to directly verify by experiments.

SUMMARY: Previous results of this ongoing research involved the absorption of a sound wave due to nonlinear noise in one dimension. An experiment confirmed the prediction that the amplitude of the signal decreases with distance as a gaussian due to the signal's interaction with the noise. Current investigations focused on two effects of acoustical radiation pressure due to noise. The first effect established the notion that acoustic noise can test predictions due to stochastic electrodynamics and the electromagnetic zero-point field (ZPF). Measurements were made of the force law between two rigid, parallel plates due to the radiation pressure of broadband acoustic. This constituted an acoustic analog to the Casimir effect, which is the force of attraction between two closely spaced uncharged parallel conducting plates due to the ZPF. However, in contrast to the ZPF Casimir effect, band limited acoustic noise can cause the force to be attractive *or* repulsive as a function of separation between the plates. The second effect involved an acoustic radiometer similar to the well-known Crooke's electromagnetic radiometer, where vanes with black and white sides rotate when exposed to light of sufficient intensity. The acoustic apparatus was constructed with panes having reflective (metal) sides and absorptive (foam) sides, which rotate when exposed to intense uniform noise in an enclosure. The radiation pressure is negligible in the electromagnetic case; the vanes rotate due to thermal effects associated with the gas. In the acoustic case, however, the rotation is due to radiation pressure, as confirmed by an approximate comparison of experimental data with the theory.

PUBLICATIONS:

Larraza, Andrés and Denardo, Bruce, "An Acoustic Casimir Effect," *Physics Letters A*, Vol. 248, pp. 151-155, 1998.

Larraza, Andrés, Holmes, Christopher D., Susbilla, Robert T., and Denardo, Bruce, "The Force Between Two Parallel Rigid Plates Due to the Radiation Pressure of Broadband Noise: An Acoustic Casimir Effect," *Journal of the Acoustical Society of America,* Vol. 103, pp. 2267-2272, 1998.

Larraza, Andrés, "A Demonstration Apparatus for an Acoustic Analog of the Casimir Effect," *American Journal of Physics*, 1999, to appear.

Larraza, Andrés, "Some Acoustic Analogs to Zero Point Field Effects," *Quantum Aspects of Beam Physics,* P. Chen, (ed.), World Scientific, 1998, to appear.

Simmons, Timothy G., Denardo, Bruce, Larraza, Andrés, and Keolian, Robert, "An Acoustic Radiometer," *Journal of the Acoustical Society of America,* Vol. 103, No. 5, Pt. 2, p. 2763, 1998.

Larraza, Andrés, Holmes, Christopher D., Susbilla, Robert T., and Denardo, Bruce, "An Acoustic Casimir Effect," *Journal of the Acoustical Society of America,* Vol. 103, No. 5, Pt. 2, p. 2763, 1998.

CONFERENCE PRESENTATIONS:

Larraza, Andrés, "Some Acoustic Analogs to Electromagnetic Zero Point Field Effects: Static and Dynamic Casimir Effects," Advanced ICFA Beam Dynamics Workshop on Quantum Aspects of Beam Physics, Monterey, CA, 4-9 January 1998.

Simmons, Timothy G., Denardo, Bruce, Larraza, Andrés, and Keolian, Robert, "An Acoustic Radiometer," Acoustical Society of America, Seattle, WA, 20-26 June 1998.

Larraza, Andrés, Holmes, Christopher D., Susbilla, Robert T., and Denardo, Bruce, "An Acoustic Casimir Effect," Acoustical Society of America, Seattle, WA, 20-26 June 1998.

DoD KEY TECHNOLOGY AREAS: Other (Radiation Pressure)

KEYWORDS: Radiation Pressure, Casimir Effect, Random Waves

DEVELOPMENT OF QUANTUM DEVICE MODELS

James H. Luscombe, Associate Professor
Department of Physics
Sponsor: Naval Postgraduate School

OBJECTIVE: The goal of this program is to develop theoretical models of the electronic, magnetic and structural properties of materials and systems at the nanometer length scale. While the primary emphasis is on developing models of heterostructure quantum electron devices, there is also an interest in nano-scale magnetic systems and quantum computing. This is a continuing project.

SUMMARY: There were three separate thrusts to the research this year. (1) The effects of deliberate compositional modifications to semiconductor superlattices were examined theoretically with a view to producing high-quality Bloch oscillations, which are high-frequency electron oscillations that can produce TeraHertz radiation. (2) A new numerical method was developed to compute what are known as Wigner 3*j* and 6*j* coefficients. The Wigner coefficients are numbers that are required in models of the magnetic properties of molecular clusters containing a relatively small number (4-10) of magnetic atoms. Magnetic molecular clusters have possible applications as ultra-dense information storage systems. A classical spin approximation was developed to predict the magnetic properties of molecular clusters. Predictive models of the nuclear-magnetic-resonance (NMR) spin-lattice relaxation time in small magnetic clusters were continued to be developed. (3) Possible technologies were looked at that could be used to develop quantum computers. Of these NMR features as one possible candidate.

PUBLICATIONS:

Luban, M. and Luscombe, J.H., "Dynamical Localization of Electrons in Aperiodic Superlattices," *Physical Review B*, Vol. 57, No. 15, pp. 9043-9049, 1998.

Luscombe, J.H. and Luban, M., "Classical Heisenberg Model of Magnetic Molecular Ring Clusters: Accurate Approximates for Correlation Functions and Susceptibility," *Journal of Chemical Physics*, Vol. 108, No. 17, pp. 7266-7273, 1998.

Luscombe, J.H. and Luban, M., "Simplified Recursive Algorithm for Wigner 3*j*- and 6*j*-Symbols," *Physical Review E*, Vol. 57, No. 6, pp. 7274-7277, 1998.

Luban, M., Reynolds, J.P., and Luscombe, J.H., "Variational Tight-Binding Theory of Excitons in Compositionally Modified Semiconductor Superlattices," *Superlattices and Microstructures*, 1998, accepted.

Luscombe, J.H. and Luban, M., "Time Correlation Functions: Revealing the Dynamical Content of Thermal Equilibrium," *American Journal of Physics*, 1998, accepted.

Luscombe, J.H., "A Modern Course in Statistical Physics," *American Journal of Physics*, 1998, accepted.

Luscombe, J.H., Luban, M., and Reynolds, J.P., "Variational Tight-Binding Theory of Excitons in Compositionally Modified Semiconductor Superlattices," *Bulletin of the American Physical Society*, Vol. 43, p. 232, 1998.

Luban, M., Jang, Z., and Luscombe, J.H., "Proton Spin-Lattice Relaxation Rate for Magnetic Molecular Ring Clusters," *Bulletin of the American Physical Society*, Vol. 43, p. 218, 1998.

CONFERENCE PRESENTATIONS:

Luscombe, J.H., Luban, M. and Reynolds, J.P., "Variational Tight-Binding Theory of Excitons in Compositionally Modified Semiconductor Superlattices," Meeting of the American Physical Society, Los Angeles, CA, 16-20 March 1998.

Luban, M., Jang, Z., and Luscombe, J.H., "Proton Spin-Lattice Relaxation Rate for Magnetic Molecular Ring Clusters," Meeting of the American Physical Society, Los Angeles, CA, 16-20 March 1998.

THESES DIRECTED:

Rice, J., "Future Satellite Technology: The Role of Nanoelectronics," Master's Thesis, Naval Postgraduate School, September 1998.

Franciose, R., "Spin and Magnetism: Two Transfer Matrix Formulations of a Classical Heisenberg Ring in a Magnetic Field," Master's Thesis, Naval Postgraduate School, June 1998.

Duvall, J., "High Precision Evaluation of Wigner 3*j* and 6*j* Coefficients," Master's Thesis, Naval Postgraduate School, June 1998.

DoD KEY TECHNOLOGY AREAS: Electronics, Materials, Processes, and Structures, Modeling and Simulation

KEYWORDS: Nanoelectronics, Nanotechnology, Nanomagnetism

APPLICATION OF HYPERSPECTRAL IMAGING TO NAVAL APPLICATIONS

Richard C. Olsen, Associate Professor
Department of Physics
Sponsors: Naval Research Laboratory and Naval Postgraduate School

OBJECTIVE: To address the application of multispectral and hyperspectral imaging to Naval needs, to participate in activities utilizing HYDICE and other instruments, and to analyze data collected during these experiments.

SUMMARY: Hyperspectral image data have been acquired from experimental sensors and are being analyzed using non-literal techniques. The objectives are to identify target signatures and other features of interest in land and littoral scenes. As a particular focus, change detection was pursued.

THESES DIRECTED:

Behrens, Richard J., "Change Detection Analysis with Spectral Thermal Imagery," Master's Thesis, Naval Postgraduate School, September 1998.

Sanders, J., "Target Detection and Classification at Kernel Blitz 1997 Using Spectral Imagery," Master's Thesis, Naval Postgraduate School, December 1998.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Remote Sensing, Targeting, Trafficability

RADIANT BRASS EXPLOITATION

Richard C. Olsen, Associate Professor
Philip L. Walker, Associate Research Professor
Department of Physics
Sponsor: Navy Tactical Exploitation of National Capabilities (TENCAP) Office

OBJECTIVE: To write a proposal and test plan to develop a method of using satellite data to predict the performance of laser designators at desert sites.

SUMMARY: The proposal was written up and submitted to TENCAP. A method of approach for this problem was devised and a test plan is being written. Funding is expected shortly.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Environment, Lasers, Transmission

NON-IMAGING INFRARED

Richard C. Olsen, Associate Professor
Department of Physics
Sponsor: Secretary of the Air Force

OBJECTIVE: To address the application of data acquired with non-imaging infrared systems to military and civilian problems. The primary civil application is the identification and tracking of volcanic ash plumes. The initial military application is battlefield awareness, particularly bomb damage assessment (BDA).

SUMMARY: Modeling of volcanic ash plumes vs. water clouds was done. Data were acquired from several volcanic eruptions late in 1998 from the Cobra Brass sensor, which should allow for comparison to the model. Several data sets taken from military operations were acquired, which should prove helpful in the assessment of techniques for BDA.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Remote Sensing, National Systems

ANALYSIS OF PLASMA AND FIELD DATA FROM POLAR SATELLITE PLASMA SOURCE INSTRUMENT (PSI) OPERATIONS

Richard C. Olsen, Associate Professor
Department of Physics
Sponsor: National Aeronautics and Space Administration-Marshall Space Flight Center

OBJECTIVE: Analyze charge control data from the plasma source instrument on the NASA POLAR satellite mission.

SUMMARY: The POLAR satellite was launched on 24 February 1996. The Plasma Source Instrument (PSI) was successfully operated for the first time on 15 April 1996. After a decade of effort, the plasma source performed as intended, grounding the satellite frame to the ambient plasma potential. This allowed highly sensitive measurements of the ambient plasma characteristics to be made. A survey of the plasma and field data collected during the first year of operations was made, and a special class was given at NPS in the area of spacecraft charging.

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Spacecraft Charging, Spacecraft-Environment Interactions

AN EXAMINATION OF 3D, BROADBAND ACOUSTIC PROPAGATION PHYSICS IN A LITTORAL OCEAN ENVIRONMENT - AN EXTENSION TO AN OFFICE OF NAVAL RESEARCH (ONR) PRIMER FIELD STUDY IN THE MID-ATLANTIC BIGHT (FY98)

Kevin B. Smith, Assistant Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: The scientific objective of this work is to study the physics and predictability of 3-D, broadband acoustic propagation upslope onto the continental shelf in the presence of strong oceanographic frontal features, specifically in the vicinity of the mid-Atlantic Bight.

SUMMARY: Special note: This funding was originally intended for the FY97 project of the same name. Due to mid-year cutbacks, my ONR sponsors withheld $16,000 until FY98. However, this project did continue under a new name with additional funding in FY98 (see the following research summary) and the summary and all products of this research are listed there.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation, Other (3-D Acoustic Propagation, Geoacoustic Inversion, Littoral Environments)

KEYWORDS: Underwater Acoustic Propagaion, Azimuthal coupling, Littoral Environments

AN EXAMINATION OF 3D ENVIRONMENTAL VARIABILITY ON BROADBAND ACOUSTIC PROPAGATION NEAR THE MID-ATLANTIC BIGHT (FY98)

Kevin B. Smith, Assistant Professor
Department of Physics
Sponsors: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: To continue analysis of the PRIMER summer '96 acoustic data and begin analysis of winter '97 acoustic data. This analysis will primarily focus on the influence of 3-D azimuthal coupling due to bathymetric features and ocean fronts near the shelf break of the mid-Atlantic Bight, the frequency selectivity of up-slope/cross-front propagation, plane-wave beam variability through a fluctuating front with non-linear soliton wave activity, and use of various data for geoacoustic

inversion studies. The results of this analysis will provide guidance for the use of active and passive sonar systems near shelf break regions.

SUMMARY: This research was a continuation of work under the Primer initiative sponsored by the Office of Naval Research to study acoustic propagation in the region of the North Atlantic Bight off the coast of New Jersey. This region is of interest due to the combination of sloping bathymetry near the continental shelf and the strong oceanographic frontal features associated with the Gulf Stream. The general purpose of this project was to study the effects of the frontal region on acoustic propagation onto the shelf. Specifically, this work focussed on the influence of three-dimensional propagation effects and their influence on the prediction of broadband measurements in similar oceanographic regions. Studies of two-dimensional, broadband propagation were also performed to examine temporal variability of plane-wave beam arrivals. Attempts were made to invert for geoacoustic parameters and environmental effects on optimal frequency propagation.

PUBLICATIONS:

Smith, K.B., "A Three-Dimensional Propagation Algorithm Using Finite Azimuthal Aperture," *Journal of the Acoustical Society of America*, 1998, submitted.

Smith, K.B., Rojas, J.G., Miller, J.H., and Potty, G., "Geoacoustic Inversions In Shallow Water Using Direct Methods and Genetic Algorithm Techniques," *Journal of the Advanced Marine Science and Technology Society*, 1998, submitted.

Potty, G.R., Miller, J.H., Lynch, J.F., and Smith, K.B., "Tomographic Mapping of Sediments in Shallow Water," *Journal of the Acoustical Society of America*, 1998, submitted.

Smith, K.B., Rojas, J.G., Miller, J.H., and Potty, G., "Geoacoustic Inversions in Shallow Water Using Direct Methods and Genetic Algorithm Techniques," *Proceedings of Pacific Ocean Remote Sensing Conference '98*, pp. 703-707, Qingdao, China, 28-31 July 1998.

Smith, K.B., "Three-Dimensional Propagation Effects: Modeling, Observations, and Suggested Benchmark Cases," *Journal of the Acoustical Society of America*, Vol. 103, p. 2989, 1998.

CONFERENCE PRESENTATIONS:

Smith, K.B., Rojas, J.G., Miller, J.H., and Potty, G., "Geoacoustic Inversions in Shallow Water Using Direct Methods and Genetic Algorithm Techniques," Pacific Ocean Remote Sensing Conference '98, Qingdao, China, 28-31 July 1998.

Smith, K.B., "Three-Dimensional Propagation Effects: Modeling, Observations, and Suggested Benchmark Cases," Acoustical Society of America, Seattle, WA, 20-26 June 1998.

THESIS DIRECTED:

Rojas, José G., "Geoacoustic Inversion Using Direct Methods on Ambient Noise and Explosive Acoustic Data in a Shallow Water Waveguide," Master's Thesis, Naval Postgraduate School, March 1998.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (3-D Acoustic Propagation, Geoacoustic Inversion, Littoral Environments)

KEYWORDS: Underwater Acoustic Propagation, Azimuthal Coupling, Littoral Environments

VARIANT AUTOCORRELATION MATCHING TECHNIQUES FOR PASSIVE TRANSIENT LOCALIZATION (FY98)

Kevin B. Smith, Assistant Professor
Department of Physics
Ching-Sang Chiu, Professor
Department of Oceanography
Sponsors: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: The scientific objective of this work is to study the influence of environmental and signal variability on a localization algorithm based on autocorrelation matching. Both synthetic data (to be generated) and real data will be used. Synthetic data will also be provided to other investigators testing different algorithms as well as environmental inversions from real data.

SUMMARY: Environmental variability influences on transient source localization were one focus of this study. Parameters such as sound speed, sound speed gradients, sediment layer, and water depths were altered and realistic range-dependent fluctuations caused by internal waves, solitons, or oceanographic fronts were injected. The effects of these various types of environmental mismatches on the performance of a localization algorithm were examined independently and combined to produce a realistic estimate of the resultant range-depth error. An emphasis was the quantification of the upper bounds on these environmental uncertainties for successful localization. In addition, real data was analyzed and processed through the localization algorithm. The algorithm employed to quantify localization degradation was based on autocorrelation matching (both time-domain and frequency-domain). The main purpose for using this algorithm was its simplicity. A PE model was used to establish the transfer function replicas. Copies of the synthetic transfer functions with environmental variability were provided to other investigators addressing the robustness of different localization and classification algorithms.

PUBLICATION:

Smith, K.B., Brune, J., and Chiu, C.-S., "Passive Transient Localization Using Signal Autocorrelation Matching," *Proceedings of 4th European Conference on Underwater Acoustics*, pp. 9-14, 21-25 September 1998.

CONFERENCE PRESENTATION:

Smith, K.B., Brune, J., and Chiu, C.-S., "Passive Transient Localization Using Signal Autocorrelation Matching," 4th European Conference on Underwater Acoustics, Rome, Italy, 21-25 September 1998.

THESES DIRECTED:

Correa, Arthur F. Bettega, "Shallow Water Acoustic Variability and Influences On Autocorrelation Matching Localization Algorithms," Master's Thesis, Naval Postgraduate School, December 1998.

Brune, Joachim, "Passive Transient Localization Using Autocorrelation Matching Techniques," Master's Thesis, Naval Postgraduate School, March 1998.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Sensors, Other (Localization)

KEYWORDS: Parabolic Equation Model, Autocorrelation Matching, Matched Field Processing, Transient Localization

BASIC RESEARCH IN BURSTING BUBBLES AND AEROSOL SOURCE FUNCTIONS

Donald E. Spiel, Associate Research Professor
Department of Physics
Sponsors: Office of Naval Research and National Science Foundation

OBJECTIVE: The objective of this continuing research is to determine the parameters of bursting ocean bubbles relevant to air-sea interaction and the marine boundary layer. Included are the number, size, and ejection parameters of both jet and film droplets.

SUMMARY: The parameters describing the birth of film droplets originating from bubbles bursting on sea water surfaces were measured. Results were obtained for bubble sizes D_b from 2 to 14.6 mm equivalent volume diameter. It was shown, contrary to earlier reports, that the films of all bubbles with D_b up to at least 14.6 mm burst in an orderly manner in which a hole appears at a well defined location, usually the film's edge, and propagates from there gathering up the film's mass into a toroidal ring as it progresses. This process is enabled because surface tension provides the force required to sustain the centripetal accelerations. Film drops are created when beads, of sufficient size, form along the length of the toroidal ring and surface tension is insufficient to maintain the centripetal accelerations at these accumulation points. Pieces of the ring break loose and leave the toroidal ring along paths tangential to the bubble's cap. It was shown that only bubbles larger than 2.4 mm-diameter can launch film droplets by this means and that this begins when the film has rolled up through an angle of about 31 (independent of both bubble size and (theoretically) surface tension. Film drop spray patterns recorded on MgO coated cylindrical shells surrounding the burst bubbles yield film drop numbers and trajectories. In addition, film drop size distributions, their speed of launch and the speed at which the film opens were determined as a function of bubble size. The droplet sizes measured are substantially larger than most previous estimates and, with a high probability, these droplets follow downward trajectories which lead them to impact the surface. A strong inference may be drawn that these impacts give birth to secondary droplets which are smaller than their parents and which have upward velocity components.

PUBLICATION:

Spiel, D.E., "On the Births of Film Drops From Bubbles Bursting on Seawater Surfaces," *Journal of Geophysical Research*, Vol. 103, pp.24907-24918, 1998.

DoD KEY TECHNOLOGY AREAS: Other (Environmental Effects)

KEYWORDS: Air-Sea Interaction, Jet Drops, Film Drops, Aerosols, Gas Exchange

MESOSCALE MODELING FOR ATMOSPHERIC TURBULENCE, PHASE II

Donald L. Walters, Associate Professor
Department of Physics
Douglas K. Miller
Department of Meteorology
Sponsor: Washington, D.C.

OBJECTIVE: To adapt state-of-the-art of large mesoscale numerical models, MM5 and COAMPS for computing electro-optical parameters for National Technical applications.

SUMMARY: The Mellor-Yamada 2.5 model parameterization used in the MM5 and COAMPS mesoscale models was found to be incorrect for stable atmospheres. The stable atmosphere turbulent kinetic energies were essentially zero. We have found that by altering the eddy and thermal diffusivity functions, forcing them to match recent experimental results gives optical turbulence results that agree microthermal balloon results. Comparing ETA and NOGAPS initial starting runs, it appears that usable forecasts of optical parameters out to 12-15 hours are possible. This prediction capability has a critical impact on the USAF Air Borne Laser program and other national programs.

PUBLICATIONS:

Walters, D.L. and Miller, D.K, "The Use of Mellor-Yamada 2.5 Level Mesoscale Models to Compute Turbulence in the Stable Atmosphere," *Journal of Applied Meteorology*, to be submitted.

Walters, D.L. and Miller, D.K., "Evolution of an Upper Troposphere Turbulence Event-Comparison of Observations to Numerical Simulations," *Proceedings of the Annual American Meteorological Society Meeting*, Dallas, TX, 12 January 1999.

THESIS DIRECTED:

Ambrose, C.R., "Strehl-Ratio Probabilities for Phase-Only Adaptive Optics," Master's Thesis, Naval Postgraduate School, December 1998.

DoD KEY TECHNOLOGY AREAS: Other (Adaptive Optical Systems, Imaging Systems)

KEYWORDS: Battlespace Environments, Atmospheric Turbulence, Adaptive Optics, Mesoscale Models

ATMOSPHERIC OPTICAL TURBULENCE MEASUREMENTS

Donald L. Walters, Associate Professor
Department of Physics
Sponsor: U.S. Air Force Research Laboratory

OBJECTIVE: To develop high resolution, real time sensor systems to measure the magnitude and source of severe optical degradation.

SUMMARY: The atmosphere is the primary limitation to military use of lasers and other optical systems. Adaptive optical systems are under development to compensate for phase perturbations introduced by the turbulent atmosphere but there are cost and performance limitations. The midday optical performance of the Starfire Optical range was worse than measurements made a decade ago for similar environments. Using a pair of 1-m vertical resolutions acoustic sonar systems, It was shown that a convective thermal plume forms on the south face of the mountain where the 1.6 m aperture system is located. The facility performance and the success of future planned experimental program could improve by nearly a factor of two at another location on the top on the west face of the mountain. Using the NPS data collected in January and February 1998, and collaborated by optical measurements made during March-June, 1998, a command decision was made by the primary USAF sponsor in Washington, DC to relocate the entire facility to the optimal position.

DoD KEY TECHNOLOGY AREAS: Other (Adaptive Optical Systems, Imaging Systems)

KEYWORDS: Battlespace Environments, Atmospheric Turbulence, Adaptive Optics, Sonar

PUBLICATIONS/PRESENTATIONS

JOURNAL PAPERS

Colson, W.B., "Short-Wavelength Free Electron Lasers in 1997," *Nuclear Instruments and Methods in Physics Research,* A407, pp. 26-29, 1998.

Denardo, Bruce, "Nonanalytic Nonlinear Oscillations: Christiaan Huygens, Quadratic Schrödinger Equations, and Solitary Waves," *Journal of the Acoustical Society of America,* Vol. 104, pp. 1289-1300, 1998.

Kesselring, M., Colson, W.B., Wong, R., and Sheffield, R.L., "Simulations of the LANL Regenerative Amplifier FEL," *Nuclear Instruments and Methods in Physics Research,* A407, II-23, 1998.

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Luban, M. and Luscombe, J.H., "Dynamical Localization of Electrons in Aperiodic Superlattices," *Physical Review B*, Vol. 57, No. 15, pp. 9043-9049, 1998.

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O'Neal, Daniel M. and Baker, Steven R., "Results of Underwater Ambient Noise Measurements in Three Large Tank Exhibits at the Monterey Bay Aquarium," *Journal of the Acoustical Society of America*, Vol. 103, p. 2908, 1998.

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Spiel, D.E., "On the Births of Film Drops From Bubbles Bursting on Seawater Surfaces," *Journal of Geophysical Research*, Vol. 103, pp.24907-24918, 1998.

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THE USE OF RIGID POLYURETHANE FOAM AS A LANDMINE BREACHING TECHNIQUE

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The results of a feasibility test using Rigid Polyurethane Foam (RPF) as an operational anti-personnel mine counter-mine technique are presented. RPF, at a given density and thickness, can withstand the explosive effects of anti-personnel blast mines and mitigate or neutralize the effects of surface laid anti-vehicular mines. A 12-inch thick, 4 pound per cubic foot foam block completely contained a 10-gram explosive charge of PETN while a 30-inch foam block with the same density contained a 30-gram charge. A 24-inch thick pad supported 50 passes of an M88A2 Recovery Vehicle, crushing the foam no more than 2-3 inches throughout the length of a 56-foot foam roadway. Underneath this roadway, simulated land mines set at 14 psi were not triggered by the passage of an M88A2 and a HMMWV. Our experiments indicate that RPF can provide additional traction in muddy conditions and set-off explosives connected to trip wires. The pressure and trafficability experiments were conducted at the Waterways Experiment Station, Vicksburg, MS, in July-August 1997, and the explosive experiments were conducted at the Energetic Materials Research and Testing Center (EMRTC) of the New Mexico Institute of Mining and Technology, Socorro, NM, in August and October 1997.

KEYWORDS: Explosives, Landmines, Rigid Polyurethane Foam, Countermine

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Conventional Weapons

SUPERSONIC FLOW PAST TWO OSCILLATING AIRFOILS

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James Luscombe, Department of Physics
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Supersonic flow past two oscillating airfoils with supersonic leading edge locus is analyzed using an elementary analytical theory valid for low frequencies of oscillation. The airfoils may have arbitrary stagger angle. This approach generalizes Sauer's solution for a single airfoil oscillating at small frequencies in an unbounded supersonic flow.

It is shown that this generalization can provide an elementary theory for supersonic flow past two slowly oscillating airfoils. This aerodynamic tool will facilitate the evaluation of pressure distributions and consequently the calculation of moment coefficient. Torsional flutter boundaries are computed. The results for the pitch-damping coefficient are the same when compared with previous analysis. For arbitrary frequencies a linearized method of characteristics was outlined.

The elementary theory that has been developed in the thesis can be used for flutter evaluation of aircraft carrying external stores. The result of the thesis is the derivation of the pitch-damping coefficient which is necessary to predict the flutter conditions.

DoD TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Flutter Analysis, Structures

TRANSIENT LOCALIZATION IN SHALLOW WATER ENVIRONMENTS

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In this work, the robustness of a simple, Bartlett-type processor based on matching broadband signal autocorrelation functions is investigated. Measures of robustness to be examined include the size of the localization footprint on the ambiguity surface and the peak-to-sidelobe levels in the presence of environmental mismatch and noise. A full-wave PE model is used to produce broadband replicas. Both model-generated synthetic signals, which provide baseline results, and measured pulses in a shallow water environment are analyzed.

This work suggests that environmental mismatch has a more significant effect on the localization performance than noise. It also suggests that, as long as the noise level is not higher than the signal level, the localization performance will not be significantly affected. This is to be expected, since for white noise the majority of the influence on the autocorrelation function occurs at zero lag which has been removed in the localization algorithms. It is also shown that the autocorrelation matching in the time-domain is generally more useful for smaller bandwidths at low frequencies, which has been observed in previous work, whereas the autocorrelation matching in the frequency-domain is better suited for larger bandwidths and higher frequencies.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Autocorrelation Matching, Transient Localization, Shallow Water

MODELING A JOINT COMBAT IDENTIFICATION NETWORK

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Today's battlefield is much more heterogeneous than in the past. With the emphasis on joint operations both within the U.S. military and in consort with coalition nations, the need for communications and sharing of tactical information across service and national boundaries has never been greater. A combat identification (CID) network that enables force's positions on the battlefield to be displayed at the appropriate granularity for the various levels of commanders would be a valuable tactical and strategic asset.

This thesis explores the possible network architectures and protocols available to implement such a system and determines, through modeling and simulation, the optimal design to minimize time performance of the flow of information through the network. Using a realistic scenario as a basis, system-engineering principles were used to generate an optimal network architecture from the design parameters chosen. The optimal design was determined to be a network consisting of an Asynchronous Transfer Mode (ATM) access type, asymmetric transmit and receive of messages, and network flow control implementation. Additionally, units on the battlefield should be grouped together by type within a region and the highest bandwidth possible should be used.

KEYWORDS: Combat Identification, Situational Awareness, Combat ID, Network Modeling

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Command, Control and Communications, Modeling and Simulation

INVESTIGATION OF A SHIPBOARD WATER SCREEN FOR INFRARED GUIDED CRUISE MISSILE DEFENSE

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The most serious threat any modern ship faces on the modem battlefield is the proliferation of anti-ship missiles. As technology advances, it is certain that these missiles will only become smarter and more lethal. Many of these missiles will employ infrared (IR) seekers (stand alone or in conjunction with radar) to improve target classification and recognition, as well as to defeat conventional RE seeker countermeasures.

This research investigates the use of IR signature suppression from a water screen to delay detection, cause the missile to break lock, or seduce the selected aimpoint away from the most vulnerable areas. A series of proof of concept experiments were conducted to investigate several water screen types. The U.S. Army NVEOD program called FLIR92 was used to evaluate several imaging systems. The FLIR92 performance output and the water screen effect data, from the proof of concept experiments, were applied to a modified range detection probability program called ACQUIRE. Real world atmospheric data from the Gulf of Oman were applied to the model. The effect of a water screen over the entire ship, as well as over specific hot spots, was studied. The water screen suppressed the ship's IR signature. The degree of suppression was highly dependent on the quantity and quality of water screen involved.

The concept, proven in experiment and validated by computer models, was then applied to different tactical applications. The computer simulation shows a 1.2-meter mist screen reduced the detection range by 25% for a destroyer. Presenting a bow/stem aspect and a mist screen achieved a detection range that is 63% less than that of a normal beam aspect. Partial screening may also be use as an effective mean of IR seeker seduction. Furthermore, it may be possible to shift the seeker aim point to areas of less vulnerability.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors, Modeling and Simulation

KEYWORDS: Ship, Infrared, IR, Suppression, Masking, Defense, Stealth

PIN AND MAGNETISM: TWO TRANSFER MATRIX FORMULATIONS OF A CLASSICAL HEISENBERG RING IN A MAGNETIC FIELD

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Nanometer scale fabrication and experimental investigations into the magnetic properties of mesoscopic molecular clusters have specifically addressed the need for theoretical models to ascertain thermodynamic properties. Technological applications germane to these inquiries potentially include minimum scale ferromagnetic data storage and quantum computing. The one-dimensional nearest neighbor Fleisenberg spin system accurately models the energy exchange of certain planar rings of magnetic ions. Seeking the partition function from which a host of thermodynamic quantities may be obtained, this thesis contrasts two transfer matrix formulations of a classical Heisenberg ring in a magnetic field. Following a discussion of the transfer matrix technique in an Ising model and a review of material magnetic characteristics, a Heisenberg Hamiltonian development establishes the salient integral eigenvalue equation. The 1975 technique of Blume *et al* turns the integral equation into a matrix eigenvalue equation using Gaussian numerical integration.This thesis alternatively proposes an exactly formulated matrix eigenvalue equation, deriving the matrix elements by expanding the eigenvectors in a basis of the spherical harmonics. Representing the energy coupling of the ring to a magnetic field with symmetric or asymmetric transfer operators develops pragmatically distinctive matrix elements; the asymmetric yielding a simpler expression. Complete evaluation will require follow-on numerical analysis.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures; Modeling and Simulation

KEYWORDS: Nanomagnetism, Heisenberg Ring in a Magnetic Field, Magnetic Molecular Clusters, High Spin Molecule Thermodynamics, Partition Function Generation Via Approximate Versus Exact Matrix Eigenvalue Equation Formulations

DISCRETE-MODE SOURCE DEVELOPMENT AND TESTING FOR NEW SEISMO-ACOUSTIC SONAR

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A seismo-acoustic sonar concept that uses guided interface waves (Rayleigh or Scholte) is being developed to detect buried ordnance in the sea floor and beach sediments. This thesis describes the initial research conducted into the design, construction, and field testing of possible seismic sources that excite preferentially the interface waves desired for use in such a system. The theory of elasticity shows that seismic interface waves have elliptical particle velocity orbits in the vertical plane along the path of propagation. It was therefore decided that to selectively excite the desired interface waves, a harmonic source employed at the interface must induce elliptical particle motion in this plane. Several exploratory sources were developed to produce this type of excitation. Field tests of the discrete-mode sources developed were conducted to evaluate this hypothesis, but due to the non-optimum nature of the experimental sources, perfect discrete source excitation was not obtained. However, it was found that the medium itself acted as a selective filter for the interface waves after a few tens of meters of propagation. The experimental results obtained here suggest that the basic concept of discrete-mode excitation looks promising.

DoD KEY TECHNOLOGY AREA: Other (Mine Warfare, Mine Countermeasures)

KEYWORDS: Seismo-Acoustic Sonar, Seismic Surface Waves, Rayleigh Waves, Scholte Waves, Buried Ordnance Detection, Mine Detection

THE MACH-ZEHNDER COUPLER

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This thesis is the second in a series which investigates the possibility of creating a code-shift-keying (CSK) optical receiver using single-mode 2x2 couplers and fiber optical delay lines to construct Mach-Zehnder couplers which comprise the main building block of the CSK receiver. There were two main goals of this thesis research. The first was to investigate design and construction modifications which would lower the system loss of a previously designed Mach-Zehnder coupler. As a result of this research, the system loss was reduced from 10.5 dB to 3.3 dB by changing the design to eliminate an unnecessary stage and by replacing several mechanical connections with fusion splices. The second goal was to find a method to measure the inherent phase shift of a 2x2 fiber optical coupler. Two separate methods were developed and implemented, and a third previously developed method was used to verify the results. All three methods provided experimental values between 145∞ and 149∞. This thesis develops the theory that explains the discrepancy between the measured values and the ideal value of 180∞ for the inherent phase shift

KEYWORDS: Fiber Optic Receiver, Mach-Zehnder Coupler, Interferometry

DoD KEY TECHNOLOGY AREAS: Electronics, Sensors, Command, Control, and Communications

CHARACTERIZATION AND MAGNETIC AUGMENTATION OF A LOW VOLTAGE ELECTROMAGNETIC RAILGUN

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In the near future armored vehicles will be fielded with reactive armor which cannot be defeated by today's chemically propelled munitions. Today's munitions are limited to muzzle velocities less than the speed of sound in the chemical propellant which is about 1.8 km/s. Electromagnetic launch technologies have the ability to launch projectiles at velocities in excess of 2 km/s and may be able to defeat the reactive armor. Not only can electromagnetic launch technologies be used as an anti-tank weapon, but also it can be used as anti-missile defense.

To investigate electromagnetic launch technologies and the effects of augmentation a 44 cm railgun was constructed and tested. The railgun was powered by a capacitor bank of fourteen 330 V, 600 mF capacitors. The velocity of the projectile, the voltage across the capacitors and the current through the rails were measured. The augmentation of the gun with a permanent magnetic field increased the velocity of the projectile by 85% while air injection augmentation had no effect.

KEYWORDS: Electromagnetic Railgun, Electromagnetic Launch Technology, Railgun Augmentation

DoD KEY TECHNOLOGY AREAS: Conventional Weapons, Electronics, Ground Vehicles

OPTIMUM SYMMETRICAL NUMBER SYSTEM PHASE SAMPLED DIRECTION FINDING ANTENNA ARCHITECTURES

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A new interferometer direction finding array architecture based on the optimum symmetrical number system (OSNS) is presented. OSNS arrays are capable of unambiguous high-resolution direction finding with as few as three elements, with multiple baseline options. The OSNS DF antenna architecture being investigated uses the OSNS to decompose the analog spatial filtering operation into a number of parallel sub-operations (moduli) that are of smaller complexity. One two-element interferometer is used for each sub-operation and only requires a precision in accordance with its modulus. A much higher spatial resolution is achieved after the sub-operations are recombined. By incorporating the OSNS concept, thedynamic range of a specific configuration of antenna element spacings and comparator arrangements can be analyzed exactly. In this thesis, the OSNS DF antenna concept was demonstrated experimentally, by designing, fabricating and measuring the performance of a three-element array at 8.5 GHz. These three elements are grouped into two pairs (channels) according to the set of relatively prime moduli ($in_1 = 6$, $in_2 = 11$). A mixer is used to determine the phase difference between each pair of elements. The output voltage from the mixer in each channel is a symmetrical folding waveform that is DC biased and amplified using a summing amplifier. The output voltage of the amplifier is amplitude analyzed using a small comparator ladder. An EEPROM is used to recombine the results of these low precision channels to yield the high resolution direction of arrival (DOA). Simulated and experimental results are presented and compared.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Direction Finding Antennas, Array Antennas, Rectangular Aperture Antennas, Open-ended Waveguides, Optimum Symmetrical Number System (OSNS), Weighted Summing Amplifier, Analog-to-Digital Converter, Comparator ladder.

REAL-TIME 3D SONAR MODELING AND VISUALIZATION

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Virtual world simulations are realistic when each individual component is simulated in a manner that reflects reality. For an underwater virtual world that simulates acoustic detection, a physically based sonar propagation model is required if ranges in excess of tens of meters are expected.

This thesis creates an application programming interface (API) for realtime 3D computation and visualization of acoustic energy propagation. The API provides features for generating complex physically based sonar information at interaction rates, and then visualizing that acoustic information. The simulation is programmed in Java and runs either as a stand-alone program or as a script in a web browser. This program generates Virtual Reality Modeling Language (VRML 97) compliant code that can be viewed from any VRML-capable browser. This approach allows the characteristics of the energy propagation to be calculated with high precision and observed in 3D.

As sonar system information bandwidth becomes larger, more intuitive ways of presenting information to a user will be required. Higher information density in a more intuitive format can free the user from integrating the data himself and allow quicker reaction times. This thesis and the API provide the foundation for fundamental advances in sonar modeling and visualization.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Modeling, Simulation, Sonar, Ray Tracing, Visualization, VRML

DESIGN, CONSTRUCTION, AND OPERATION OF THE NAVAL POSTGRADUATE SCHOOL'S ULTRAVIOLET IMAGING SPECTROMETER

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Hyperspectral imaging spectrometers produce an image comprised of the standard two-dimensional spatial scene and the corresponding spectra of each scene. Hyperspectral imaging is a relatively new and fast growing field with both commercial and military applications. Commercial applications vary from vegetation identification and mapping, surface geological identification and mapping to atmospheric composition and mapping. Military applications include target identification and classification, airborne chemical identification and mapping, and rocket plume identification.

This thesis describes the design and operation of the NPS Ultraviolet Imaging Spectrometer (NUVIS). NUVIS is a hyperspectral imaging spectrometer designed to investigate the ultraviolet region of the spectrum. NUVIS is comprised of a scanning mirror, telescope assembly using an off-axis parabolic mirror, a slit, a flat field imaging diffraction grating, an image intensified camera assembly, and the support/controlling electric and electronic hardware and software. This is part of a continuing project to build, test and use this sensor in support of military and government agencies.

KEYWORDS: Hyperspectral Imaging, Ultraviolet, Imaging Spectrometers, NUVIS, Support to Military Operations, Support to Government Agencies

DoD KEY TECHNOLOGY AREA: Sensors

THE MIE SCATTERING SERIES AND CONVERGENCE ACCELERATION

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D. Scott Davis, Department of Physics

This thesis research presents an algorithm for the precise determination of the Mie extinction efficiency parameter. The mathematical representation of the Mie parameters is in the form of an infinite series, and any technique that could be found to accelerate the convergence of the Mie series would have great commercial and military application. Results are presented that show the comparison of the rate of convergence obtained by directly summing the individual terms of the extinction efficiency parameter and the rate obtained using an existing series acceleration technique. It was found that the acceleration method employed, known as the Levin method of series transformation, proved unsuccessful in accelerating the convergence of the Mie series. However, other acceleration techniques exist and should be explored.

KEYWORDS: Mie Scattering, Levin Method, Series Acceleration

DoD KEY TECHNOLOGY AREAS: Environmental Quality, Sensors

SIMULATIONS OF THE LOS ALAMOS NATIONAL LABORATORY (LANL) 1 KW REGENERATIVE AMPLIFIER FREE ELECTRON LASER (FEL)

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The development of a high average power FEL for military applications would represent a significant improvement in missile defense, especially shipboard self-defense. The LANL regenerative amplifier FEL (RAFEL) is designed to produce an average output power of 1 kW. This FEL represents a significant increase in average power demonstrated in an FEL provides a test of the concept of combining the FEL oscillator and amplifier designs. Simulations were performed to better understand the physics behind the LANL RAFEL operation.

Simulations study the transverse effects due to optical guiding by the intense electron beam and feedback. These simulations are applied to optimizing the undulator taper rate, feedback optimization, and initial phase velocity. Additional simulations study the longitudinal effects due to short electron pulses and optical pulse development over multiple passes. Finally, simulations of the RAFEL design using an ideal beam expand on understanding of the design's basic characteristics and limitations.

KEYWORDS: Free Electron Laser, FEL, LANL, RAFEL, Missile Defense, Simulations

DoD KEY TECHNOLOGY AREAS: Directed Energy Weapons, Surface/Under Surface Vehicles - Ships and Watercraft, Manufacturing Science and Technology (MS&T)

INVESTIGATION OF HIGH FREQUENCY SHIP RADAR CROSS SECTION REDUCTION BY MEANS OF SHAPING

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Master of Science in Electrical Engineering-September 1998
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The objective of this thesis is to investigate and evaluate the effectiveness of ship radar cross section (RCS) reduction in the high frequency (HF) band by means of shaping. The study is based on a computer simulation which uses the method-of-moments to compute the RCS of a number of conventional and shaped ship geometries. It was found that a ship with canted deckhouse walls and a standard hull had little reduction in RCS relative to a conventional ship. This result shows that shaping is not as effective at these frequencies (3-30 MHz) as it is in the optical region. The hull is the major contributor to RCS near broadside. Shaping the hull did reduce the RCS slightly for the frequencies and elevation angles investigated.

DoD KEY TECHNOLOGY AREAS: Electronics, Sensors, Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

KEYWORDS: HF Radar, Ship, RCS, Method-of-Moments, CAD

WIRELESS LOCAL AREA NETWORKS: SIMULATION AND ANALYSIS

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Wireless communication is currently in a state of rapid evolution. This evolution is driven by the numerous advantages of the wireless networks. One major constraint to this evolution is the lack of standardization. Also a major concern are theinterference problems of the signal at the reception point caused by the multiple paths that the electromagnetic waves travel (multi-path interference).

This thesis presents two separate simulations. In the first, a realistic physical model of a wireless local area network is developed. In this simulation, the multi-path interference at the reception point is investigated. The results of this physics-based simulation are used to assess an important assumption in the second simulation.

In the second part, we examine the reliability of the wireless standard for the medium access control (MAC) layer, using CACI COMNET III network simulation software. This standard was published in 1997, by the IEEE's working group 802.11 and in this thesis is tested and analyzed under different network loads. One major result is that the optimum load for a five working stations wireless LAN, is from 80 to 200 packets per second. Below that load range the channel utilization is small and above that the network is overloaded.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Multipath Interference, Irradiance, Wireless Local Area Networks, CSMA\CA Wireless I-AN Protocol, Channel Utilization, Packet Delay

SIMULATION OF PROPOSED 20 KW KLYSTRON FREE ELECTRON LASER

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The Free Electron Laser (FEL) is a potential solution for the U.S. Navy's anti-ship missile point defense by providing an evolutionary increase in weapon accuracy. To become an effective weapon, the FEL will need to provide an average optical power of approximately one MW. Towards this goal, the Thomas Jefferson National Accelerator Facility (TINAF) in Newport News, Virginia is constructing the first kW EEL, and desires to improve the design to 20 kW while maintaining less than 6% energy spread. Using a klystron undulator is one potential way to accomplish this. Given design parameters of a proposed free electron laser by TINAF, this study quantifies via simulation the behaviors of gain, power and energy spread as functions of desynchronism and a klystron's disperse strength. Specifically, it shows that a conventional undulator appears capable of meeting all TINAF design requirements.

DoD KEY TECHNOLOGY AREA: Directed Energy Weapons

KEYWORDS: Free Electron Laser, Undulator, Klystron

IMPLEMENTATION AND EVALUATION OF AN INERTIAL NAVIGATION SYSTEM (INS) FOR THE SHEPHERD ROTARY VEHICLE

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An autonomous vehicle must be able to determine its global position even in the absence of external information input. To obtain reliable position information, this would require the integration of multiple navigation sensors and the optimal fusion of the navigation data provided by them.

The approach taken in this thesis was to implement two navigation sensors for a four-wheel drive and steer autonomous vehicle: An inertial measurement unit providing linear acceleration in three dimensions and angular velocity for the vehicle's global motion and shaft encoders providing local motion parameters. An inertial measurement unit is integrated with the Shepherd mobile robot and data acquisition and processing software is developed. Position estimation based on shaft encoder readings is implemented. The framework for future analysis including most general motion profiles have been laid.

The sensor's system performance was evaluated using three different linear motion profiles. Test results indicate that the shaft encoder provide a positioning accuracy better than 99% (typ. 7.5 mm for 1 m motion) under no slip conditions for pure translational motion. The IMU still requires further improvement to allow for both sensors to be combined to an integrated system.

KEYWORDS: Robotics, Sensors, Navigation, NPS, Shepherd, Rotary Vehicle

DoD KEY TECHNOLOGY AREAS: Sensors, Ground Vehicles

SIMULATION OF THE AUTONOMOUS COMBAT SYSTEMS ROBOT OPTICAL DETECTION SYSTEM

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Master of Science in Applied Physics-December 1997
Advisors: Gordon E. Schacher, Department of Physics
Donald Brutzman, Undersea Warfare Academic Group

NPS Combat Systems students learn systems engineering through a series of courses in design, development, implementation, and testing and evaluation. In the last of this series of courses, students design an autonomous robot capable of searching, acquiring, and tracking another autonomous robot having similar capabilities. The project culminates in the Robot Wars Competition, where groups of students have their robots battle each other.

This thesis is the second in a series designed to realistically simulate the robot wars battles. The end-to-end functionality of the optical detection system is modeled, and the necessary physics are implemented for effective simulation and depiction. The model uses a transfer function approach and includes all physical processes, from initial optical beacon emission to final digital control signal. Exercising the model over time using realistic robot inputs yields a simulation that closely replicates real behavior. A Virtual Reality Modeling Language (VRML) program uses data files of each Simbot's movement to generate a 3-dimensional animated scene of the detection sequence. This implemented optical model effectively simulates the SE 3015 robot optical detection system and can reproduce an actual detection and tracking sequence between two robots.

KEYWORDS: Optics, Models, Simulation, Robots

DoD KEY TECHNOLOGY AREAS: Computing and Software, Electronics, Modeling and Simulation

COMPUTER PROGRAMS SUPPORTING INSTRUCTION IN ACOUSTICS

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Second Reader: Kevin B. Smith, Department of Physics

Acoustics is a field of study not easily understood and laboratory experiments which might shed light on problems in acoustics are complex and expensive to accomplish. Computers have become a valuable tool in many fields of study in order to examine complex problems which would be difficult and expensive, if not impossible to study using traditional methods. This thesis is an extension of work previously completed by Thomas Green to support instruction utilizing the text, Fundamentals of Acoustics, Third Edition, John Wiley & Sons, Inc., by Coppens, Frey, Kinsler, and Sanders. The fourth edition of *Fundamentals of Acoustics* is currently in revision and the computer programs explained in this thesis will be used to support it. All programs utilize MATLAB™, a widely accepted programing language for accomplishing numerical analysis of engineering problems. The benefit of these programs will be very dependant on students using them in conjunction with the text.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Acoustics, MATLAB

DIGITAL DATA ACQUISITION FOR LASER RADAR FOR VIBRATION ANALYSIS

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D. Scott Davis, Department of Physics

Laser radar for vibration analysis represents a military application to develop a target identification system in the future. The problem addressed is how to analyze the vibrations of a target illuminated by the laser radar to achieve a positive identification.

This thesis develops a computer-based data acquisition and analysis system for improving the laser radar capability. Specifically, a review is made of the CO_2 laser radar, coherent detection, and data acquisition software and signal processing. These aspects form the basis for a laser radar system, using LabView software for data acquisition and signal analysis, which is capable of detecting vibrations from a stationary target. The laser radar was able to detect the frequencies of vibration of a test target. All the data can be recorded by the system. The laser radar presented could be used for further development and production of a target identification system.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: CO_2 Laser Radar Equations, Vibration Detection, Optics, Acousto-Optic Shift, Target Identification, Detectors, Data Acquisition

SIMULATIONS OF LOS ALAMOS NATIONAL LABORATORY (LANL) REGENERATIVE MEGAWATT FREE ELECTRON LASER AMPLIFIER

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Master of Science in Applied Physics-December 1997
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Robert L. Armstead, Department of Physics

The development of a speed-of-light hard-kill weapon system for military applications represents a significant advancement in technology over present conventional kinetic weapon systems. Over the past two decades, the U.S. Navy has successfully developed a megawatt-class chemical laser; however, under some maritime environments, the high power beam propagation was unable to delivery sufficient energy to kill a modern anti-ship missile (ASM) due to significant atmospheric absorption and the resulting thermal blooming process. A critical problem to resolve for the shipboard high-energy laser weapon systems is to develop a shipboard-compatible megawatt-class laser weapon at a wavelength where the atmospheric absorption is smallest. The megawatt-class Free Electron Laser (FEL) has significant advantages over conventional weapon systems and other chemical high-energy laser systems. Infinite magazine, rapid response, and wavelength tunability make the FEL a suitable and desirable shipboard weapon system.

This thesis divides into four chapters. Chapters I and II introduce the FEL and background theory of the FEL. Chapter III explores the analysis of the LANL Regenerative MW FEL Amplifier design and optimizes its efficiency. Lastly, Chapter IV summarizes the feasibility of achieving the desired efficiency.

KEYWORDS: Free Electron Laser, FEL, MW, LANL, RAFEL, Missile Defense

DoD KEY TECHNOLOGY AREA: Directed Energy Weapons

COMPARISON OF THE UNDERWATER AMBIENT NOISE MEASURED IN THREE LARGE EXHIBITS AT THE MONTEREY BAY AQUARIUM AND IN THE INNER MONTEREY BAY

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Second Reader: Thomas G. Muir, Chair of Mine Warfare

Ambient underwater acoustic noise recordings were made in three large exhibits at the Monterey Bay Aquarium and the inner Monterey Bay, with the results reported here. Observed broadband (0-6.4 kHz) acoustic noise levels ranged from 112-125 dB re 1 μP for the aquarium exhibits under normal operating conditions. Broadband acoustic noise levels of 113 dB and 116 dB re 1 μPa were observed for the nearshore and offshore bay locations, respectively.

A comparison of the noise spectrum in the aquarium's largest exhibit to that of the environment which it attempts to simulate, the offshore bay, revealed a higher noise level of approximately 15-25 dB in the exhibit for frequencies between 20 Hz and 6.4 kHz. A similar comparison of the noise spectra of the two smaller exhibits and the nearshore bay location revealed a difference of approximately 5-10 dB across the entire frequency range of 0-6.4 kHz.

Aquarium measurements with various mechanical equipment (motors, fans, pumps, sprinklers, wave machine) turned on and off highlighted some of the prominent ambient noise contributors. It was concluded that the pump machinery is the greatest contributor to ambient noise, with the strength directly related to the exhibits' proximity to the machinery room.

DoD KEY TECHNOLOGY AREA: Other (Underwater Acoustic Ambient Noise)

KEYWORDS: Ambient Noise, Noise Measurements, Aquarium, Monterey Bay

POLARIZATION EFFECTS ON INFRARED TARGET CONTRAST

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An analysis has been carried out of a data base of polarized long wave infrared images of the instrumented Research Vessel Point Sur recorded over a period of two days during the EOPACE measurements series in San Diego Bay in 1996. The measurements were made from a land site on Point Loma with an AGA780 sensor with internally mounted polarization filters. The objectives of the analysis were to determine a possible influence of target aspect angle on the polarization signature, to compare polarization contrast improvement in San Diego Bay with previous measurements in the North Atlantic, and to validate by measurement the estimation of unpolarized signature from vertical and horizontal components. 5508 images representing 70 cases with vertical, horizontal and unpolarized sequences were analyzed. Using a horizontal polarizer, target to background contrast improvement was found with a mean of 1.08 (8%) compared with the 15% found in previous measurements. Estimated unpolarized signatures from vertical and horizontal components agreed with unpolarized measurements with a slope coefficient of .85 to .99. Target signature for major ship facets and for total ship showed no discernable degree of polarization. A total of 37 IDL programs developed for this analysis can be assembled as a package for future data processing.

DoD KEY TECHNOLOGY AREA: Electronic Warfare, Sensors

KEYWORDS: Thermal Imaging, Polarization, Target Contrast, Infrared Radiation

A FUTURE SATELLITE TECHNOLOGY

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Robert L. Armstead, Department of Physics

Tiny earth-orbiting spacecraft known as nanosatellites are now possible due to breakthroughs in microelectromechanics that permit engineers to build extremely small yet fully functional devices. With today's satellite launch costs averaging around $20,000 per pound lifted into space, nanosatellites could revolutionize the future of space access by significantly reducing the size, mass, power requirements, complexity and ultimately the costs of space systems. The small satellite concept fosters a faster evolution in space science and introduces and tests state-of-the-art space technology. Of the technologies required to design a miniaturized and yet autonomous vehicle, nanoelectronics is at the forefront.

The field of nanoelectronics is primarily concerned with integrated circuit (IC) technology at geometries well below 100 nanometers. It is in this realm that the quantum mechanical nature of the electron becomes of paramount importance. With the tools of quantum physics, reduction in the size of individual transistors has yielded the quantum dot; a three-dimensional structure for confinement of a single electron. The theoretical study in this thesis will show that the width in p-n junctions is generally
underestimated for curved interfaces by textbook formulas. This result is significant for semi-cylindrical quantum dots which are the logical result of continued down scaling in semiconductor devices.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Electronics

KEYWORDS: Nanosatellites, Nanoelectronics, Solid State Physics

HYPERSPECTRAL POLARIMETRY FOR SATELLITE REMOTE SENSING

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The study of polarization of reflected light and its angular dependence is well documented. However, most measurements have been panchromatic in nature, i.e., they were taken over a broad wavelength region. A few polarization measurements have examined polarization at several specific narrow wavelength bands. These measurements can be classified as multi-spectral. Thus, previous efforts to characterize an object using polarization have not investigated a hyperspectral polarization signature.

This thesis determines the hyperspectral polarization signature of several common materials that are significant to the military. A range of materials was examined including camouflage fabrics, military paints, rubber, plastic, taggant, and glass. It is shown that a hyperspectral polarization signature, when combined with a hyperspectral reflectance signature may enhance present capabilities to detect, classify, and identify objects of military significance. This technique appears especially promising for dark objects, shiny surfaces, synthetic fabrics, and unpainted metal.

This combined approach could be realized in a hyperspectral polarimetric imaging satellite. The utility of designing such a sensor and many key design considerations are examined. Preliminary analysis suggests sensor designs for low earth and geosynchronous orbiting spacecraft may be feasible. Sensor data rate and signal-to-noise ratio will be the limiting factors in these designs.

KEYWORDS: Hyperspectral Imagery, Polarization, Polarimetry, Satellite Remote Sensing

DoD KEY TECHNOLOGY AREA: Sensors

CLASSIFIED TITLE

Joseph R. Robson, Jr.-Lieutenant, United States Navy
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Infrared remote sensors often detect thermal signatures on surfaces of naval ships induced by heating from internal sources Once thermal signatures are identified, temperature differences between various surface features can provide indication of these units' operational intentions.

This thesis demonstrates how a specific infrared remote sensing platform can be used to exploit signatures of specific military unites for intelligence Indications and Warning. Through the use of the Multisource Automatic Target Recognition with Interactive Exploitation (MATRIX) software, 18 infrared images were exploited and analyzed for temperatures. Temperature differentials were obtained between various areas along the hull and compared with departure times. A positive correlation was shown between temperature values over 60 C and departure of the selected units (U).

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Other (Intelligence, Indications and Warnings (I&W))

KEYWORDS: Imagery Intelligence, Remote Sensing, Infrared, China, Naval

GEOACOUSTIC INVERSION USING DIRECT METHODS ON AMBIENT NOISE AND EXPLOSIVE ACOUSTIC DATA IN A SHALLOW WATER WAVEGUIDE

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Second Reader: James V. Sanders, Department of Physics

The fundamental goal of this thesis is to determine the geoacoustic parameters of a shallow water seabed using direct analysis methods on ambient noise and broadband explosive acoustic data. All data considered are from the Mid-Atlantic Bight shelf break experiment that was conducted from 19 July to 9 August 1996. Simple, theoretical treatments of acoustic propagation in a shallow-water waveguide are applied to specific, measurable quantities in the data which can be inverted directly to produce estimates of bottom compressional sound speed, density, and attenuation. Shear influences are neglected throughout. Specifically, vertical coherence of the ambient noise is used to determine the sound speed contrast at the water/bottom interface, mode travel times extracted from spectrograms of explosive data are used to estimate bottom density based on the concept of an ideal waveguide effective depth, and mode attenuation as a function of range extracted from similar spectrograms are employed to estimate attenuation. These direct inversion methods are less accurate than sophisticated matched field processing techniques or direct core measurements, but they do provide a relatively simple means of obtaining reasonable estimates of ocean bottom parameters from minimal information.

DoD KEY TECHNOLOGY AREA: (Other) Environmental Characterization

KEYWORDS: Geoacoustics Inversion

DESIGN, CONSTRUCTION AND TESTING OF AN AUTONOMOUS MINE HUNTER

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Landmine detection is an immense technological problem. A small, low power metal detector would find application in concert with other search technologies. A detection circuit was designed and constructed consisting of a search coil and a CMOS exclusive OR gate forming an oscillator. This was interfaced to a microprocessor which counted the pulses from the oscillator and decided whether a detection had been made. Detection range for an anti-personnel mine like object was 14 cm at the coil centerline. A robot platform to autonomously search for landmines was constructed.

KEYWORDS: Landmine, Induction, Robot, Microprocessor

DoD KEY TECHNOLOGY AREA: Sensors

LOW LATITUDE IONOSPHERIC EFFECTS ON RADIOWAVE PROPAGATION

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This dissertation provides experimental observations and analyses that associate low-latitude transionospheric signal scintillation with transequatorial VHF radio propagation and errors in transionospheric geopositioning.

The experiment observed equatorial-region ionospheric total electron content (TEC) derived from Global Positioning System (GPS) signals using receivers on Oahu, Hawaii, Christmas Island, and Rarotonga, Cook Islands. The experiment simultaneously measured VHF transequatorial propagation of VHF television signals from Hawaii to Rarotonga.

Analysis shows that a moving second moment of vertical-equivalent TEC strongly correlates to each VHF transequatorial radio propagation event. From experimental observation analysis, the author develops models for prediction of TEP and time-space distribution of low-latitude transionospheric scintillation.

The author also develops equations that show the potential errors in time, frequency, and angle used in geopositioning solutions. These three parameters are potentially correctable using these techniques.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Low-Latitude, Ionosphere, Equatorial, Scintillation, Geopositioning, Global Positioning System, GPS, Total Electron Content, TEC, Transequatorial Propagation, TEP

APPLICATIONS AND LIMITATIONS OF TWO IMPORTANT NUMERICAL METHODS FOR THE COMPUTATION OF TRANSMISSION COEFFICIENTS

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As a consequence of the ever-shrinking sizes of nanoelectronic devices, hitherto neglected quantum effects, such as tunneling, are becoming important for device characterization. The study of electron reflection and transmission probabilities at potential barriers is one of the important areas of active research in this field.

Analytic solutions for the quantum-mechanical transmission coefficient through a potential energy profile of arbitrary shape do not exist. One conceivable method for finding the transmission coefficient through such a potential involves transfer matrices. This technique is numerically limited, unfortunately, and fails to provide adequate results for potentials of interest in the development of practical nanoelectronic devices. However, within its capabilities, the transfer matrix method is a useful reference to which other results may be compared. Another method, utilizing backward recurrence, has been proposed as a numerically stable alternative for calculating the transmission coefficient through such potentials. This second method has yet to be widely applied.

This thesis investigates the capabilities and limitations of each method, with an emphasis on their scope of applicability. Extensive programming, in the C language, has been done to examine the two methods. Output from these programs has been analyzed, and the backward-recurrence method has been shown to have wider applicability, and to be faster and much more numerically stable.

KEYWORDS: Nanoelectronics, Device Modeling, Numerical Methods, Numerical Instability, Quantum Physics, Quantum Transmission Coefficient

DoD KEY TECHNOLOGY AREAS: Electronics, Modeling and Simulation, Other (Quantum Physics, Quantum Transmission Coefficient)

SIMULATIONS OF THE PROPOSED TJNAF 20 KW FREE ELECTRON LASER

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As the Navy's role as peace enforcer in support of ground troops draws Navy combatants into the littoral warfare environment, surface combatants will have to deal with decreased reaction times while engaging ever-faster anti-ship missile threats. The Phalanx Close-In Weapon System (CIWS) does not offer sufficient accuracy or engagement ranges to fight these threats, and conventional chemical lasers, which operate at fixed wavelengths, lack the tunability to operate in a dynamic ocean environment.

The Free Elctron Laser (FEL) offers the wavelengh tunability, fast reaction times, and the pinpoint accuracy necessary to ensure protection of Navy surface combatants into the future. In support of this goal, the Navy is funding a proposed 20 kW FEL at Thomas Jefferson National Accelerator Facility (TJNAF) in Newport News, VA. This FEL will feature a klystron undulator, designed to improve gain in weak optical fields, and a loop that will feed electrons back to the accelerator. Simulations in this thesis vary the dispersive section strengths of the klystron undulator and desynchronism between the optical and electron pulses in order to find dispersive strength and desynchronism values that optimize the effects on final power and weak-field gain, while maintaining an electron energy spread less than TNJAF's goal of 6% to ensure proper feedback of electrons to the accelerator. Results show TNJF's 20 kW FEL design will reach a final power of 19.2 kW with an energy spread of 6% at desynchronism of $d = 0.03$ using a conventional undulator.

DoD KEY TECHNOLOGY AREA: Directed Energy Weapons

KEYWORDS: Free Electron Laser, Undulator, Klystron

RESIDENTIAL LIT FIREPLACE DETECTION AND DENSITY MEASUREMENT USING AIRBORNE MULTI-SPECTRAL SENSORS

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Jeffrey W. Jenner, National Aeronautics and Space Administration Michael J. Smith Chair

Both locally (San Francisco Bay Area) and nationally, evidence is mounting that particulate matter poses a serious health risk. Locally, concentrations of 10-micron particles are highest on cold nights, during the months of December and January. Analysis of the composition of these 10-micron particles suggests that a large percentage is wood smoke. Currently, there are no adequate ways to estimate the number of lit fireplaces on a given night. NASA Ames Research Center, the Naval Postgraduate School, and San Francisco Bay Area Air Quality Management District performed a joint research project to determine the feasibility of using thermal imagery to detect lit fireplaces.

This thesis addresses the use of an airborne multi-spectral remote sensing system to detect lit fireplaces. The focus is on the remote sensing equipment used for fireplace detection, the development of the test plan, airborne data collection, ground truthing and data analysis.

KEYWORDS: Remote Sensing, Multi-Spectral, Environmental Quality

DoD KEY TECHNOLOGY AREA: Environmental Quality, Sensors

ANALYSIS OF ACOUSTIC PLANE-WAVE VARIABILITY IN THE REGION OF THE MID-ATLANTIC BIGHT SHELF BREAK

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Second Reader: James V. Sanders, Department of Physics

From the summer cruise of the Mid-Atlantic Bight Experiment, conducted jointly by the Naval Postgraduate School, University of Rhode Island, and Woods Hole Oceanographic Institution, a study of acoustic plane-wave variability in the region of Mid-Atlantic Bight shelf break was conducted. The period of the experiment was from 19 July to 09 August 1996. The experiment consisted of a suite of acoustic and oceanographic sensors including three 400 Hz (100 Hz bandwidth) transceivers, one 224 Hz (16 Hz bandwidth) transceiver and two vertical line arrays (VLAs). This study involved the signal processing of data collected by a telemetry buoy, an analysis of the spatial and temporal coherence of the phones and beams of the vertical array, and the tidal and seasonal variabilities of plane-wave arrivals at the vertical array. Results of the changes in arrival time of the beams, the horizontal displacement of the front, the changes in the speed of propagation of the wave, and the change in the water temperature are discussed.

KEYWORDS: Mid-Atlantic Bight, Ocean Acoustics, Plane-Wave Beamforming, Temporal Coherence, Spatial Signal Processing, Shelf Front Tidal Response

DoD KEY TECHNOLOGY AREA: Other (Ocean Acoustics)

HIGH FREQUENCY COMPONENTS IN BOTTLENOSE DOLPHIN ECHOLOCATION SIGNALS

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Steven R. Baker, Department of Physics

The research described in this thesis is a continuation of work started by the Applied Research Laboratories of the University of Texas at Austin into the analysis of biosonar signals. Experiments conducted in 1997 on two species of small toothed whales found these species to emit significant high frequency signal components, extending to as high as 400 to 500 kHz.

To assess the importance of these high frequencies in dolphin echolocation and target identification, experiments were performed in which an acoustic filter, used to suppress the high frequencies, was placed between a dolphin and a target. Insertion Loss and Reflection Loss measurements performed on _" thick and _" thick Sound Absorbing Filters (SOAB) demonstrated their effectiveness at absorbing high frequencies above 150 kHz, with little reflectivity.

The results from one echolocation experiment, with one dolphin, showed the animal's ability to classify targets was essentially unaffected by the insertion of the filters. Analysis of the dolphin's echolocation signals showed the animal definitely compensating for the filters, by increasing its sound energy output, especially at frequencies above 100 kHz. It is anticipated that this initial experiment will lead to future research in explaining the existence of these high frequency echolocation components.

DoD KEY TECHNOLOGY AREA: Other (Biosonar and Mine Detection)

KEYWORDS: Bottlenose Dolphins, Marine Mammal Systems, Echolocation Signals, Biosonar, Mine Detection

INVESTIGATION OF THE EFFECTS OF VARIOUS NOZZLE CONFIGURATIONS ON SOLID-ROCKET-PLUME INTENSITIES AND SPECTRA

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Master of Science in Astronautical Engineering-March 1998
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Subscale rocket motors were fired and the plume signatures were measured in the infrared (IR) and ultraviolet (UV) wavelength regimes. Band-averaged and spectral data were recorded using an SR5000 IR spectrometer (2.5 to 5.5 μm range), an Agema 870 IR thermal imaging camera (3.5 to 5 μm range), and the Naval Postgraduate School UltraViolet Imaging Spectrometer (NUVIS) (325 to 405 nm range). Rocket motor nozzle geometries were varied to determine the effects of over- and under-expansion on the plume band-averaged intensity and spectra. Four different solid rocket propellants were used: X-61, NWC-278, AC-13, and AC-14. The enhanced mixing nozzle, used in conjunction with the X-61 propellant, reduced the plume signature in both the UV and IR regions. The total UV intensity of the plume decreased by about 30% and varied as function of distance from the rocket nozzle. The intensity difference was more pronounced at shorter wavelengths (325-385 nm) than at longer wavelengths (385-405 nm). The difference in power was not as large in the IR region (about 7%). Intensity results from the analysis of the NWC-278, AC-13, and AC-14 runs were inconclusive. Data from the NUVIS and Agema instruments were used to create spectra for each of the propellants. While distinct features were discernible in the UV spectra, they could not be identified with a specific atom or molecule. The IR spectra were characterized by several molecular bands attributed to a combination of CO_2, H_2O, and HCl.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Sensors

KEYWORDS: Solid Propellant Rocket, Rocket Plume Spectra, Rocket Plume Intensity, Plume Signature

A MATHEMATICAL MODEL OF KNEE KINEMATICS UTILIZING THE PRINCIPLE OF MINIMUM ENERGY

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William B. Maier II, Department of Physics

This thesis seeks to determine if the path of motion of the knee in passive flexion results from the minimization of potential energy in the joint ligaments. To investigate this hypothesis, a simulation modeling both collateral and cruciate ligaments was developed, with each cruciate ligament represented as two separate fibers. The model computed almost 8000 possible orientations of the femur during flexion through 120, with the surfaces of the femur and tibia serving as a constraint to motion. Each orientation of the femur inherently provided the position of the individual ligament attachment points, from which the extension or contraction and the potential energy of the ligament were derived. The energy of the entire six-ligament system resulted from the summation of the potential energy of individual ligaments. For each 10 of flexion, the femur position that produced the minimum energy of this six-ligament system was identified. Finally, the motion of the femur as it followed these positions was evaluated: it did not mirror known joint motion. There are several areas where further refinement of the simulation can be made before a complete evaluation of the hypothesis can be made.

DoD KEY TECHNOLOGY AREA: Biomedical

KEYWORDS: Energy Minimization, Knee, Flexion, Ligament

ESTIMATE OF MAXIMUM DETECTION RANGE FOR FORWARD LOOKING INFRARED (FLIR) FROM EOMET95 MEASUREMENT DATA

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Advisors: Alfred W. Cooper, Department of Physics
David D. Cleary, Department of Physics

FLIR sensor maximum range predictions for operational use may be based on the intersection of apparent target contrast temperature difference (DT_{app}) and sensor minimum resolvable (MRTD) or minimum detectable temperature difference (MDTD), each expressed as a function of range. Ranges obtained using the SEARAD code (MODTRAN modified for sea surface radiance) are compared with those based on Beer's Law with constant extinction coefficient. Physical and meteorological parameters for the common scenario were taken from the database of the EOMET95 measurements in Monterey Bay, with the research vessel *Point Sur* as instrumented target and measurement platform. MRTD and MDTD functions were developed as functions of range for a generic Common Module FLIR using the Johnson Criterion for resolution with a parallelepiped geometry model of the *Point Sur*. The Beer's Law results underestimate the SEARAD-based ranges by approximately 50% for detection but less for classification and identification. Replacement of Beer's Law with MODTRAN-computed transmittance reduces this discrepancy. SEARAD-based modeled sea radiance and short range contrast temperature show unexpected variation with range.

KEYWORDS: Atmospheric Optics, Infrared Sensors, FLIR

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

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